AFOSR Program Review

Formal Specification and Design of Secure Agents (99NI029)

Agent Development Environments for Large-Scale Multi-Agent, Distributed Mission Planning and Execution in Complex Dynamic Environments (99NM097)

Scott A. DeLoach

Thomas C. Hartrum

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Overview

- Problem statement, objective
- Current work, results
- Significant accomplishments/transitions
- Future direction
- Publications
  - Significant publications and total publications under the grant.
  - Also mentions in the media.
- Issues

Problem Statement

Apply software synthesis techniques to the analysis, design, and construction of intelligent agents to ensure appropriate security and communications protocols are correctly incorporated.

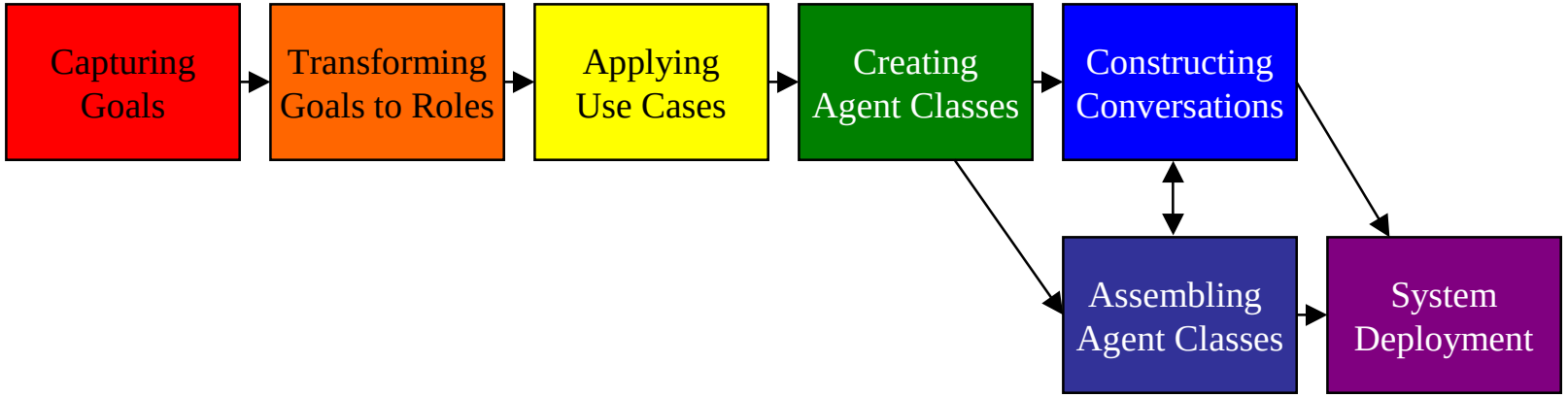
- Define a methodology and language for defining high-level behavioral specifications for multiagent systems.
- Implement a system to design and semi-automatically synthesize multiagent systems that adhere to required protocols.
- Verify that systems meet requirements.

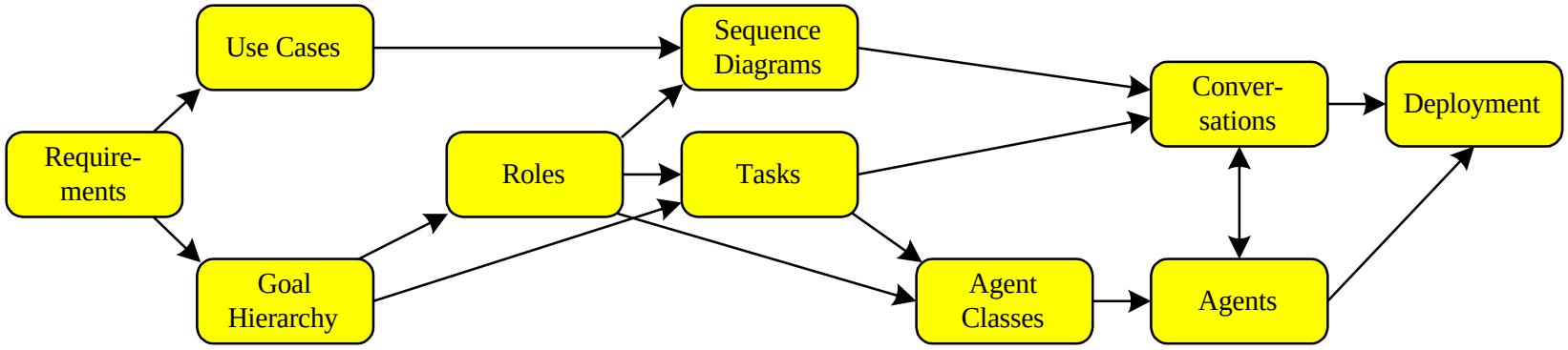
Current Results

- Multiagent Systems Engineering (MaSE)
  - Specification to code methodology for building multiagent systems
- agentTool
  - Automation for MaSE
  - Supports design, verification, and code generation
- AWSOME

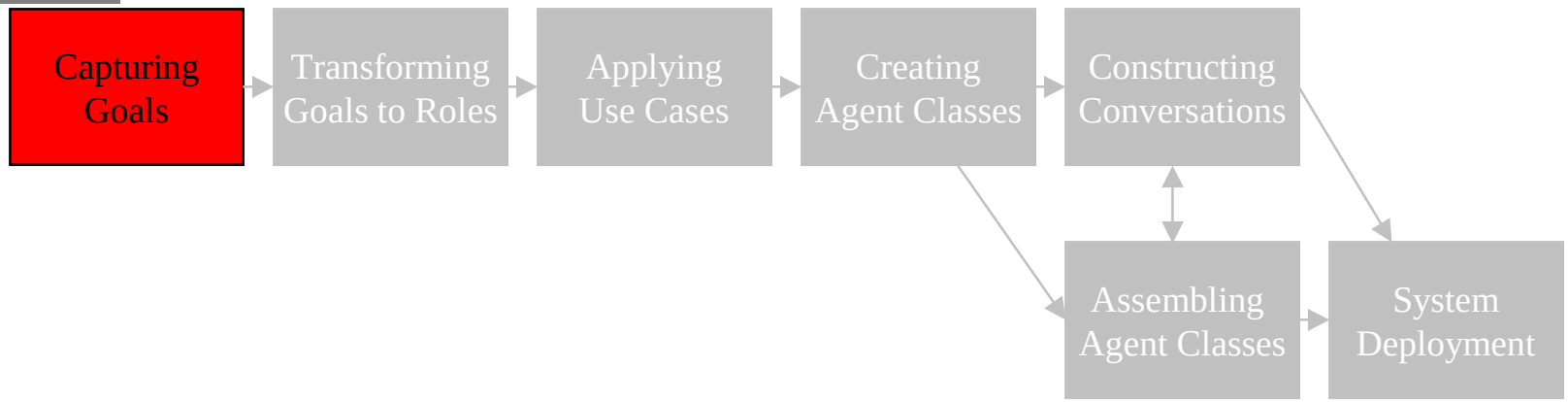
Multiagent Systems Engineering

Multiagent Systems Engineering (MaSE)

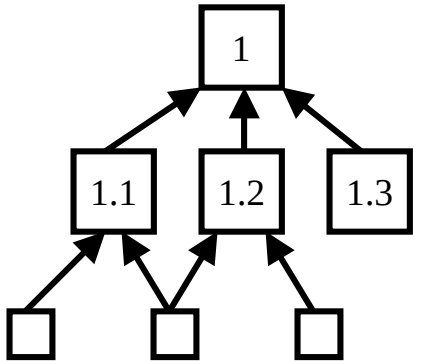




Capturing Goals

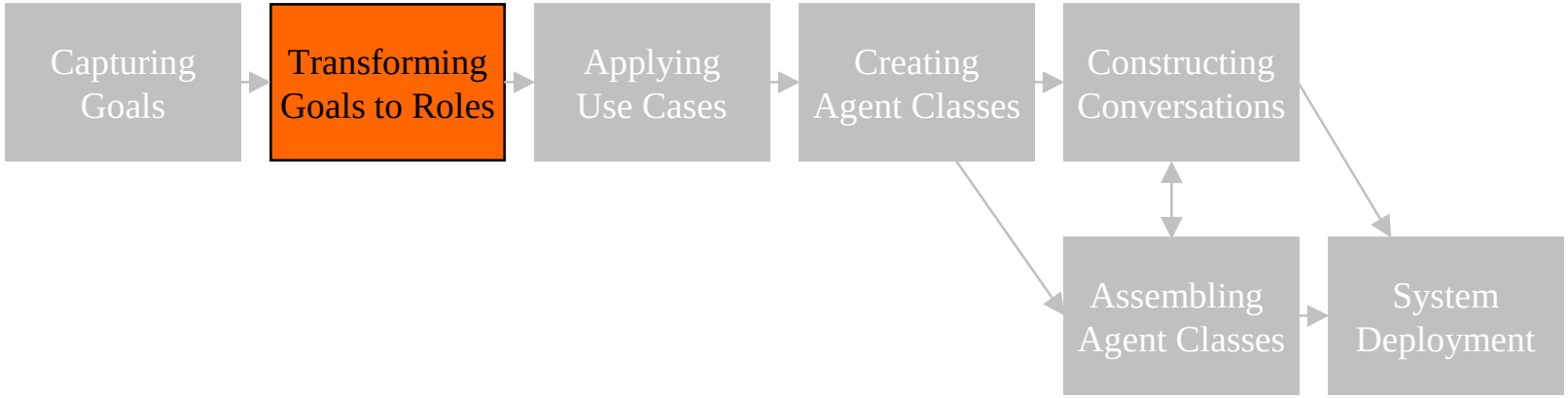


- Input
  - System specification / requirements
- Product
  - A structured hierarchy of goals
  - Use cases
- Diagrams
  - Goal hierarchy diagram

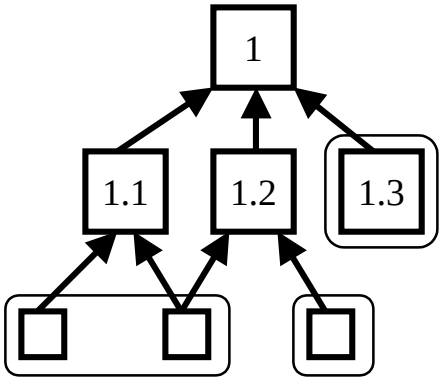


Goal hierarchy diagram (simplified)

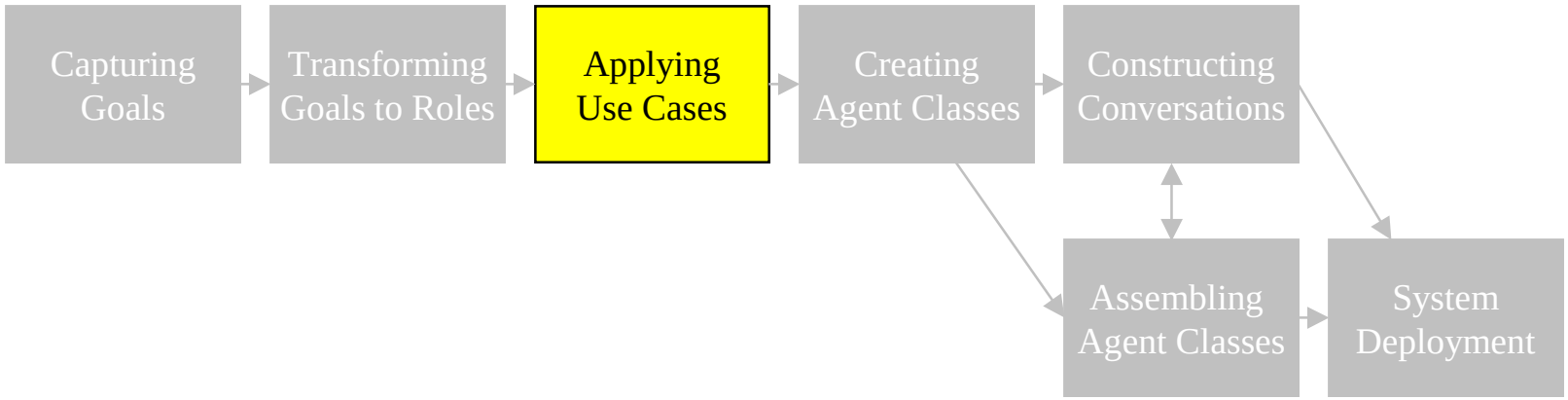
Transforming Goals to Roles



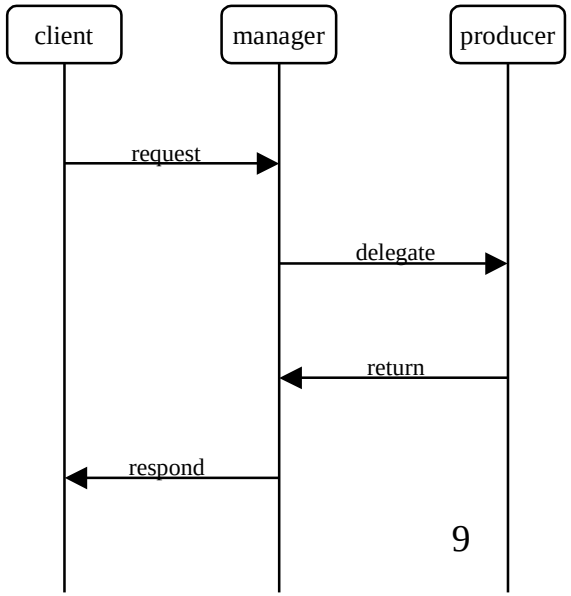
- Input
  - Goal Hierarchy Diagram
- Product
  - Agent Roles
- Diagrams
  - Role Models



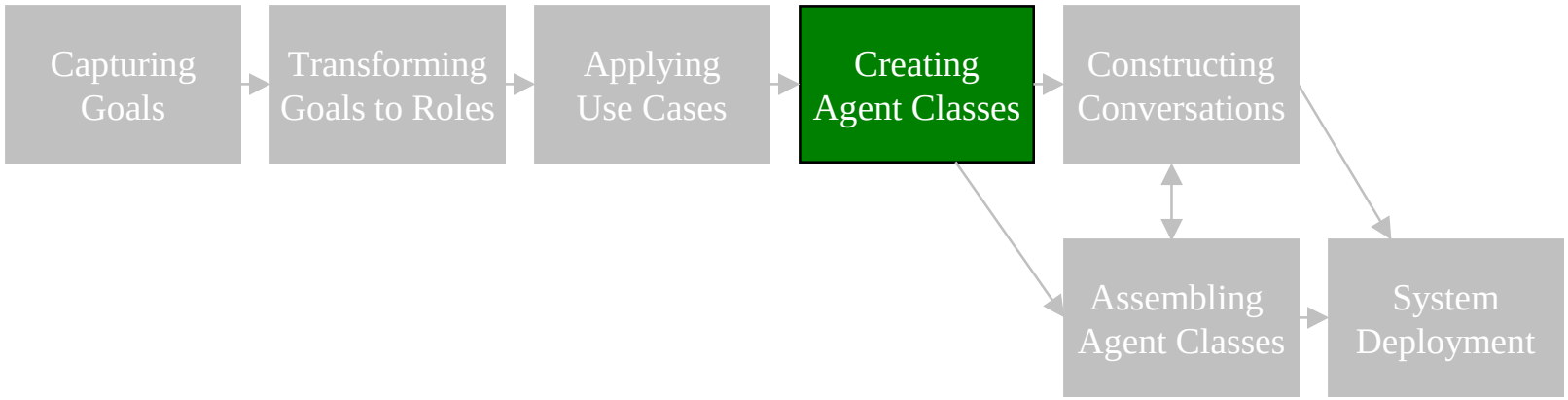
Applying Use Cases



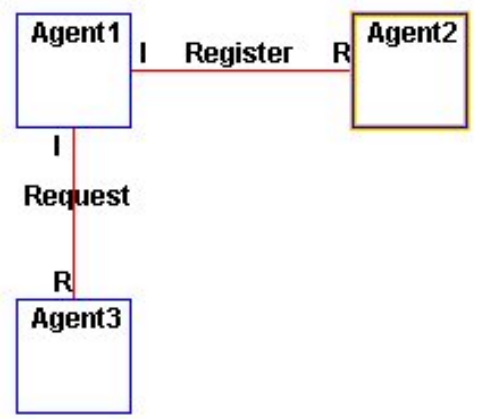
- Input
  - Use cases
  - Set of roles
- Product
  - Minimum communication paths between roles
- Diagrams
  - Sequence Diagram
  - Task Diagram



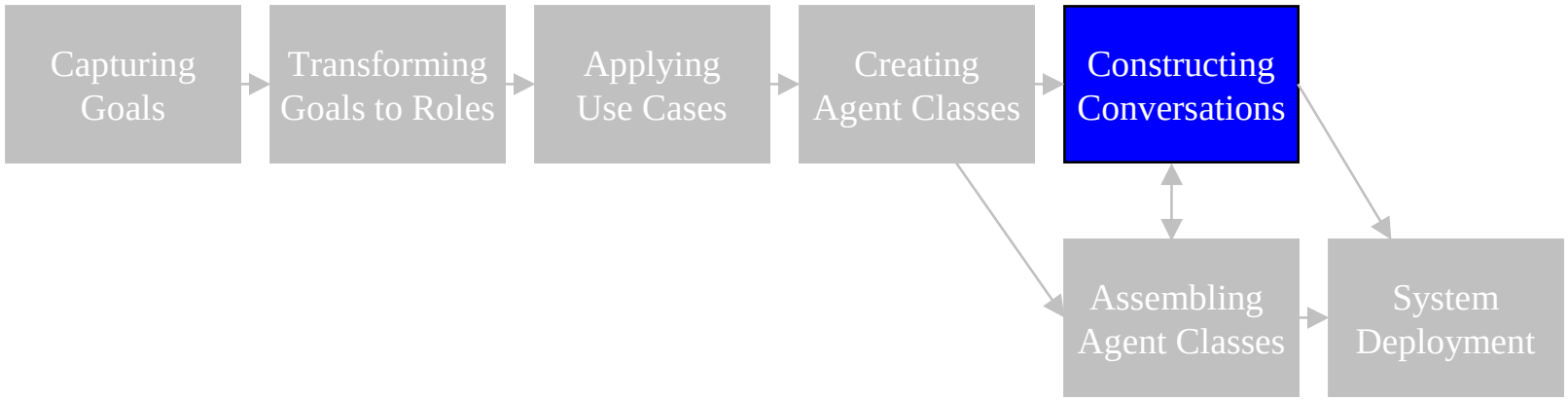
Creating Agent Classes



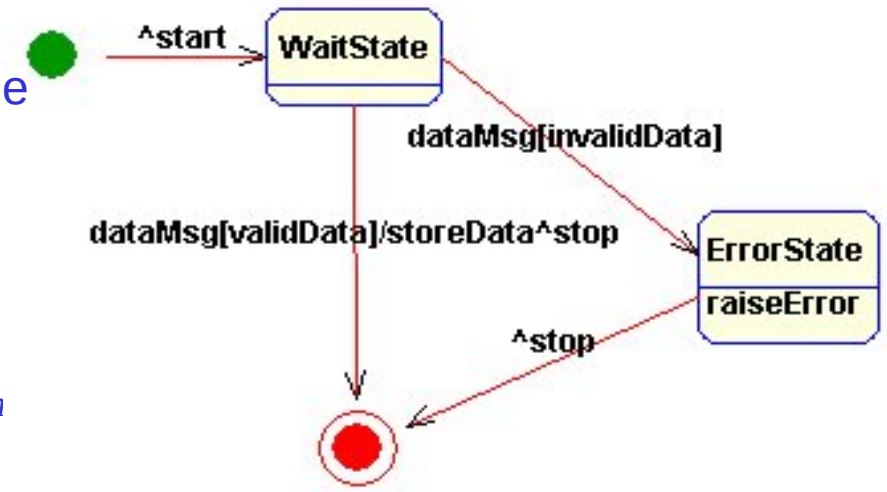
- Input
  - Agent roles
  - Tasks
- Product
  - A diagram of agent classes and conversations
- Diagrams
  - Agent Class Diagram



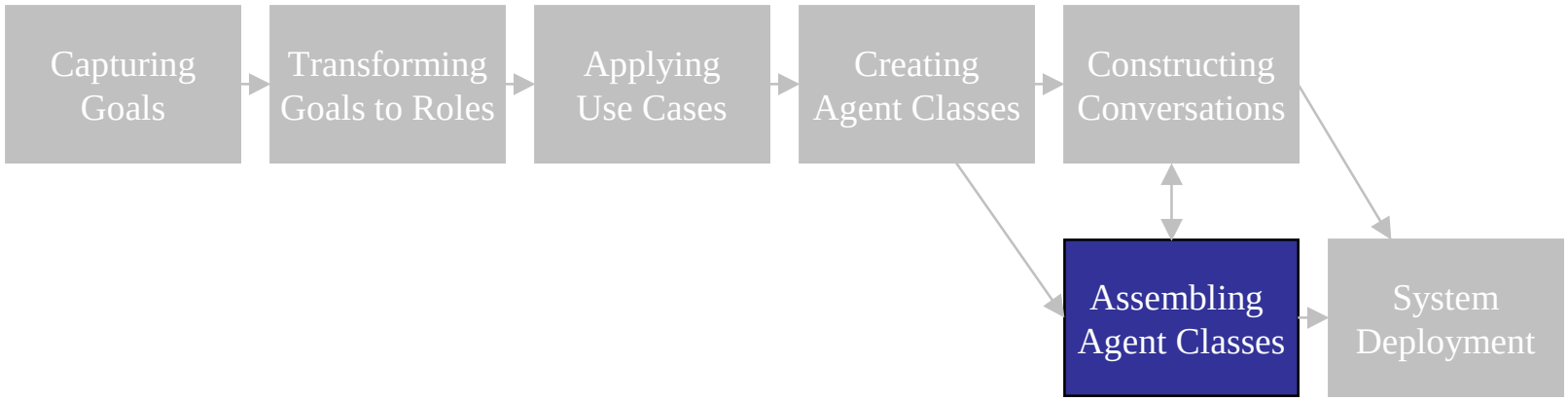
Constructing Conversations



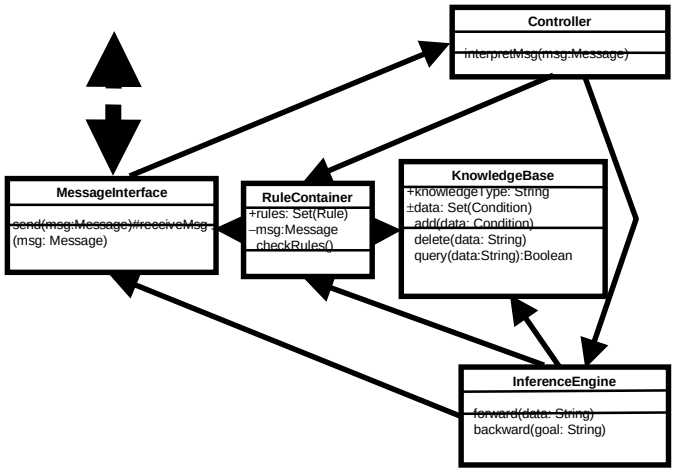
- Input
  - Agent Class Diagram
- Product
  - Conversations as graphical state tables including actions
- Diagrams
  - Conversation Diagrams



Agent Assembly



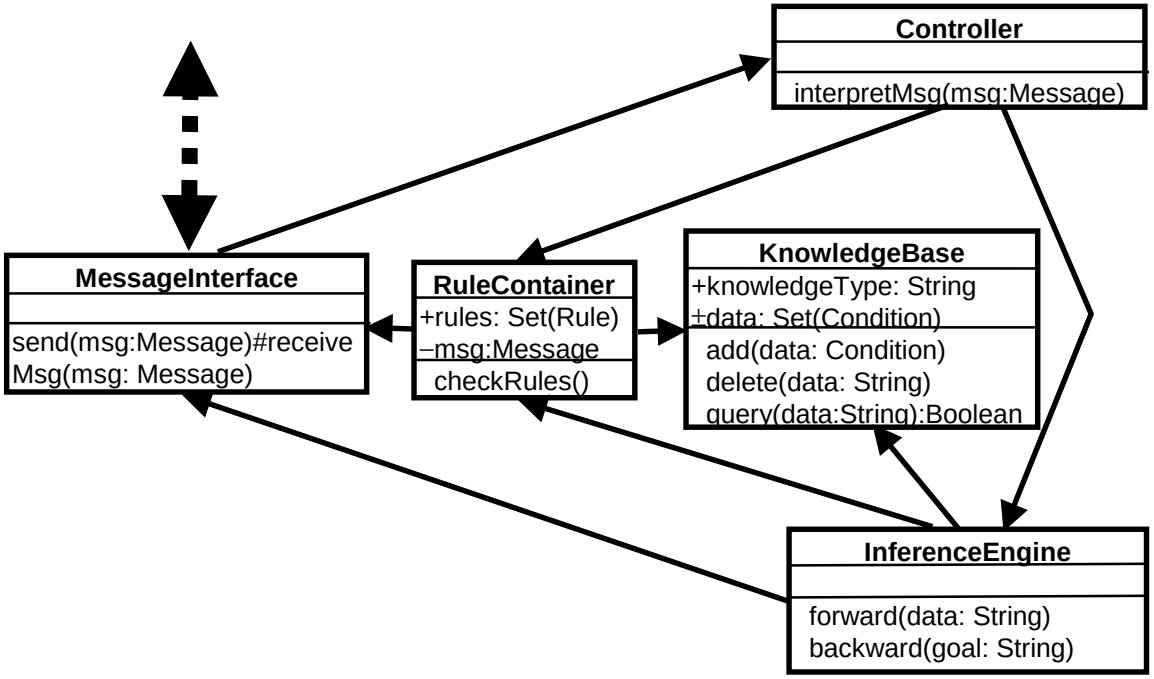
- Input
  - Agent Class Diagram
  - Conversation Diagrams
- Product
  - Complete Agent classes with components
- Diagrams
  - Agent Architecture Diagram



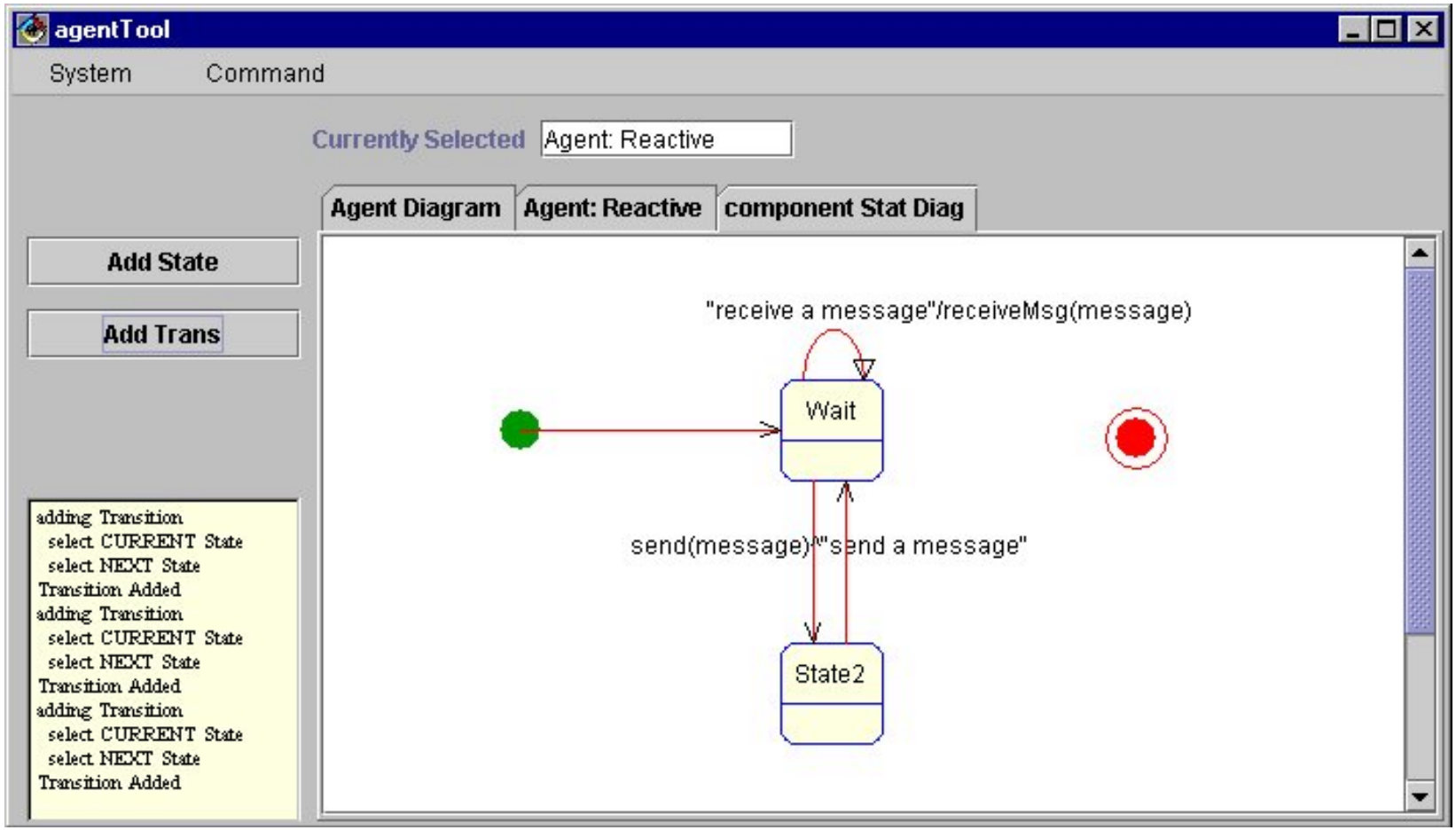
Agent Class Assembly

- Defined using Agent Definition Language (AgDL)
  - Components and connectors
    - depicts static structure of agent
  - Object Constraint Language (OCL)
    - represents low-level definitions
  - State diagrams
    - depicts dynamic aspects

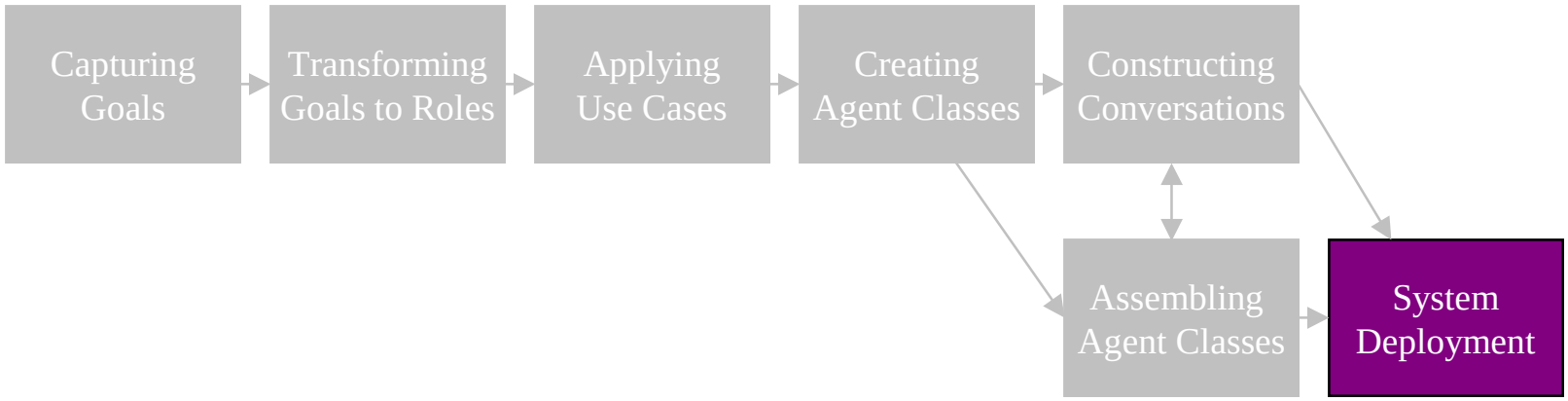
Static Model



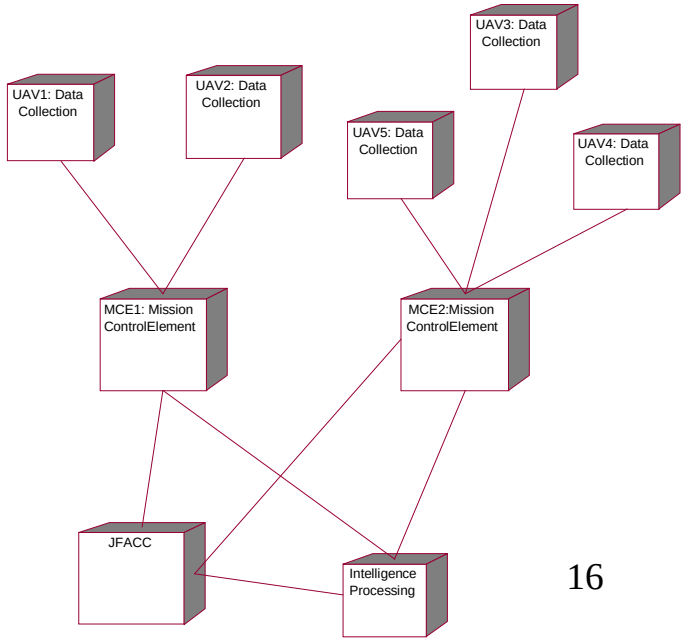
Dynamic Model



Deployment



- Input
  - Complete agent classes
- Product
  - A collection of agents
- Diagrams
  - Deployment Diagram



agentTool

agentTool

Provide users the ability to specify & design agent systems and semi-automatically generate those systems using software synthesis and component reuse techniques.

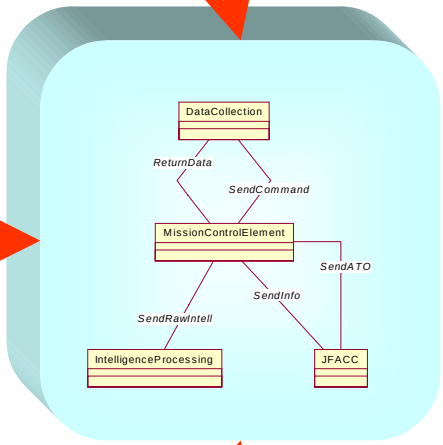
Domain Knowledge

- Multiagent Infrastructures

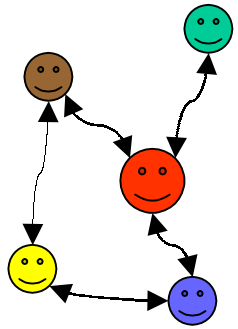
AI Components

- planners
- inference mechanisms
- search algorithms
- learning algorithms

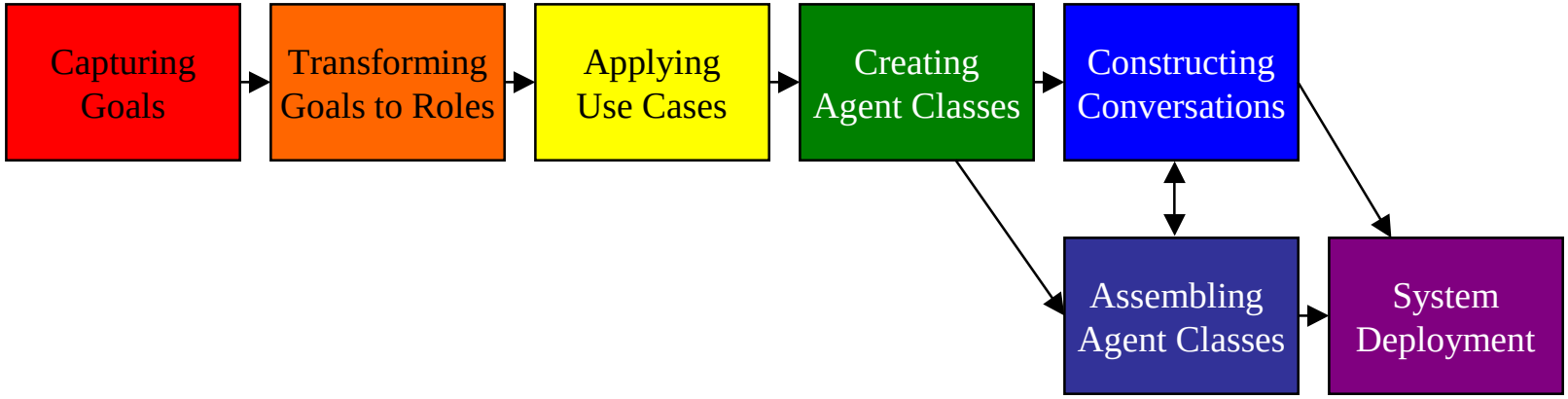
Communication & Security Protocols

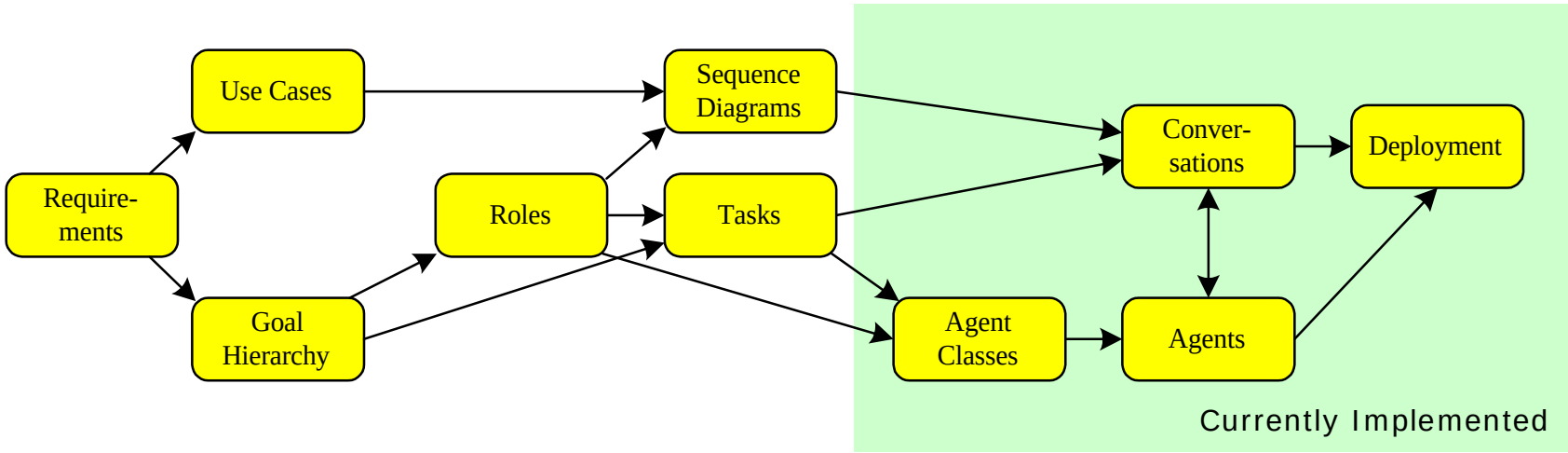


generation

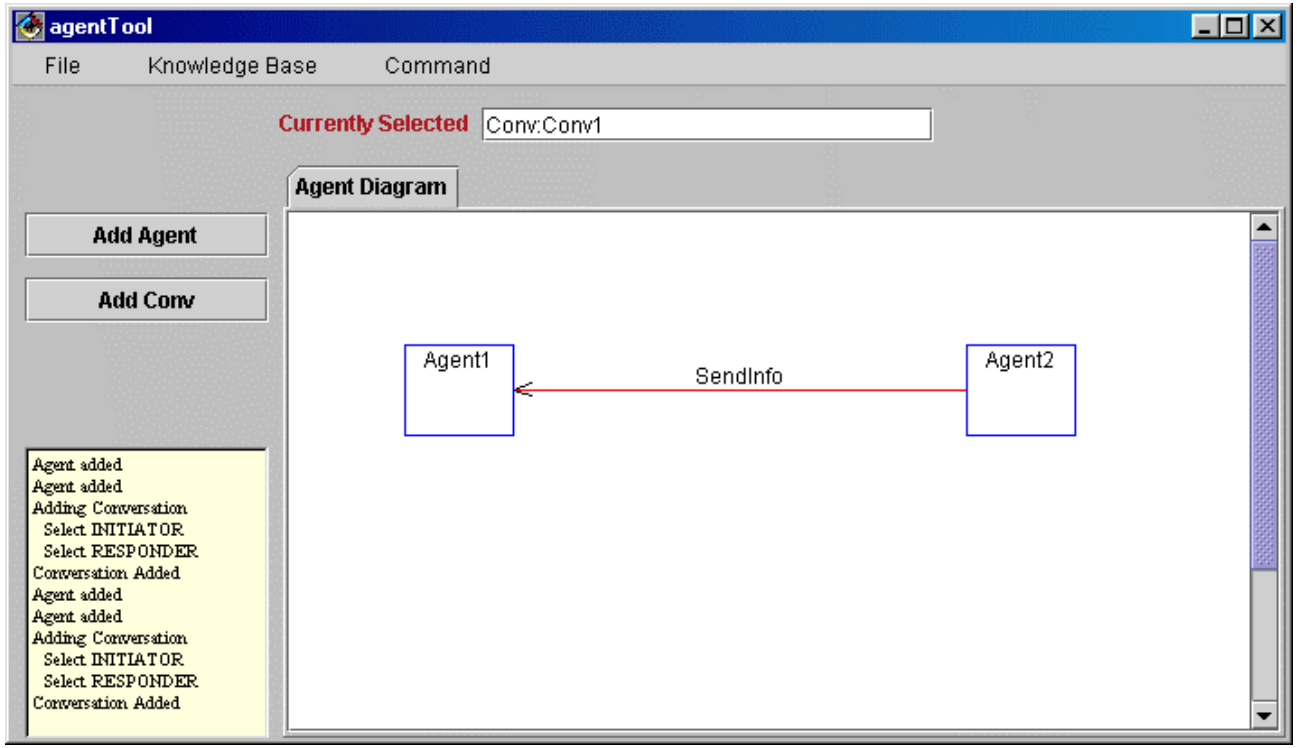


Multiagent Systems Engineering (MaSE)

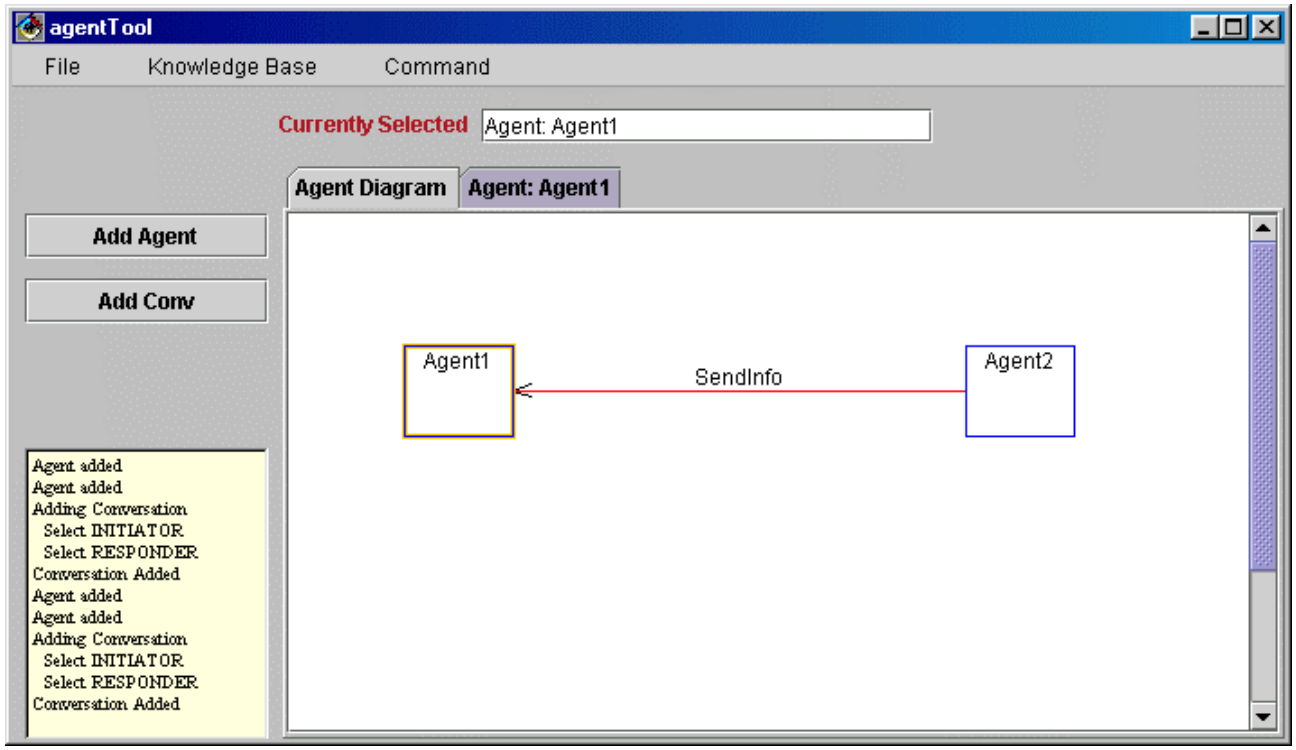




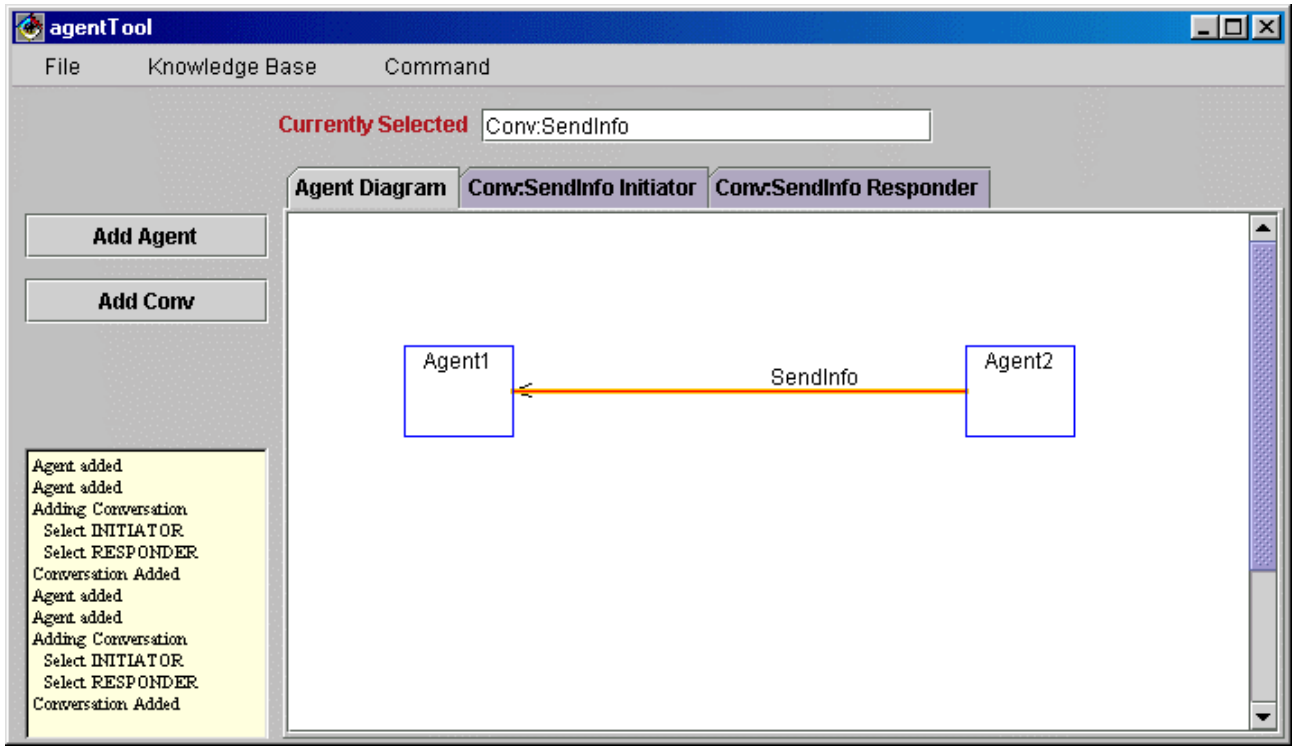
Agent Diagram



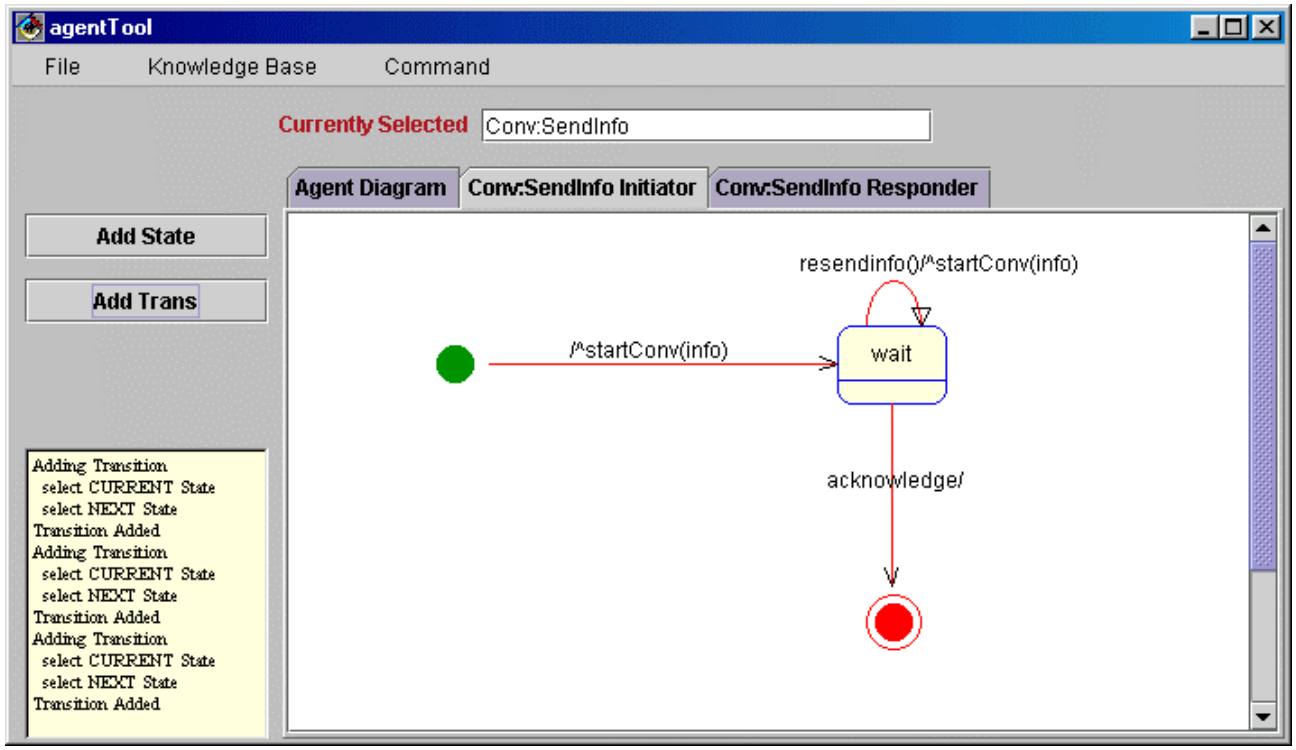
Selecting an Agent Class



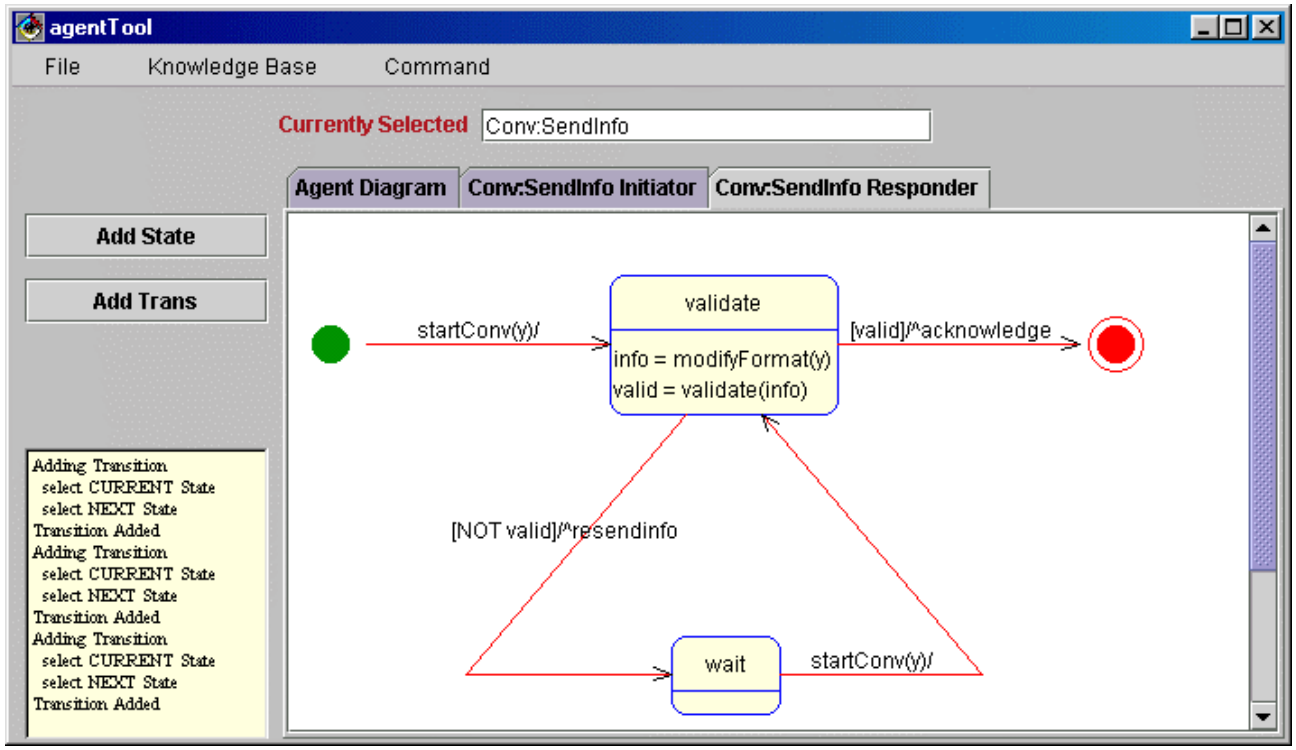
Selecting a Conversation



Conversation Diagram
(half a conversation)

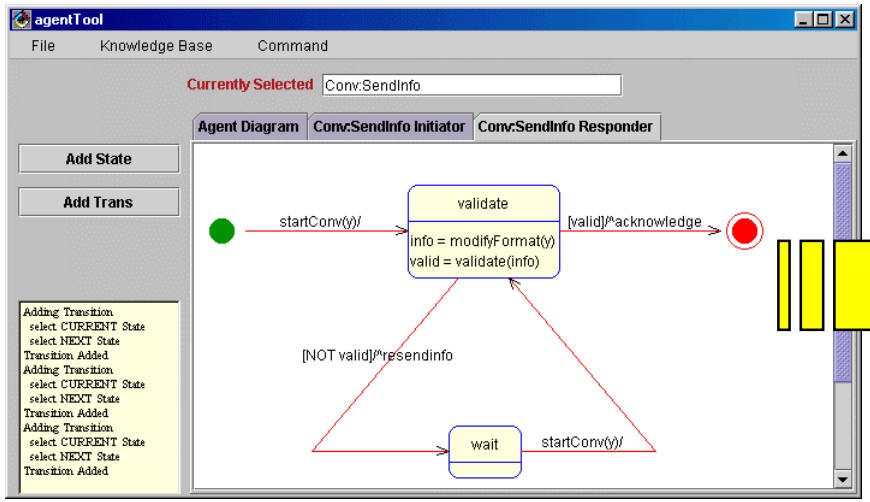


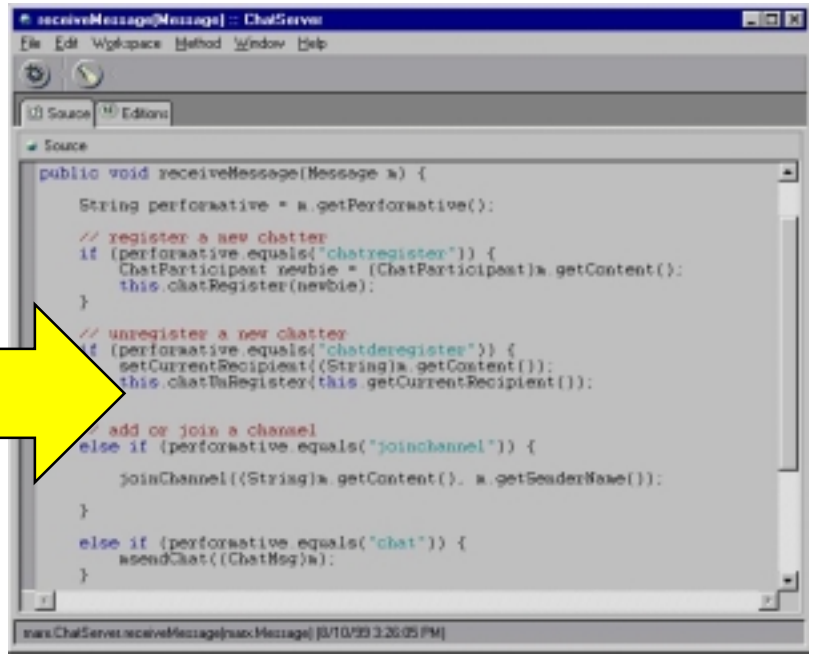
Conversation Diagram
(the other half)



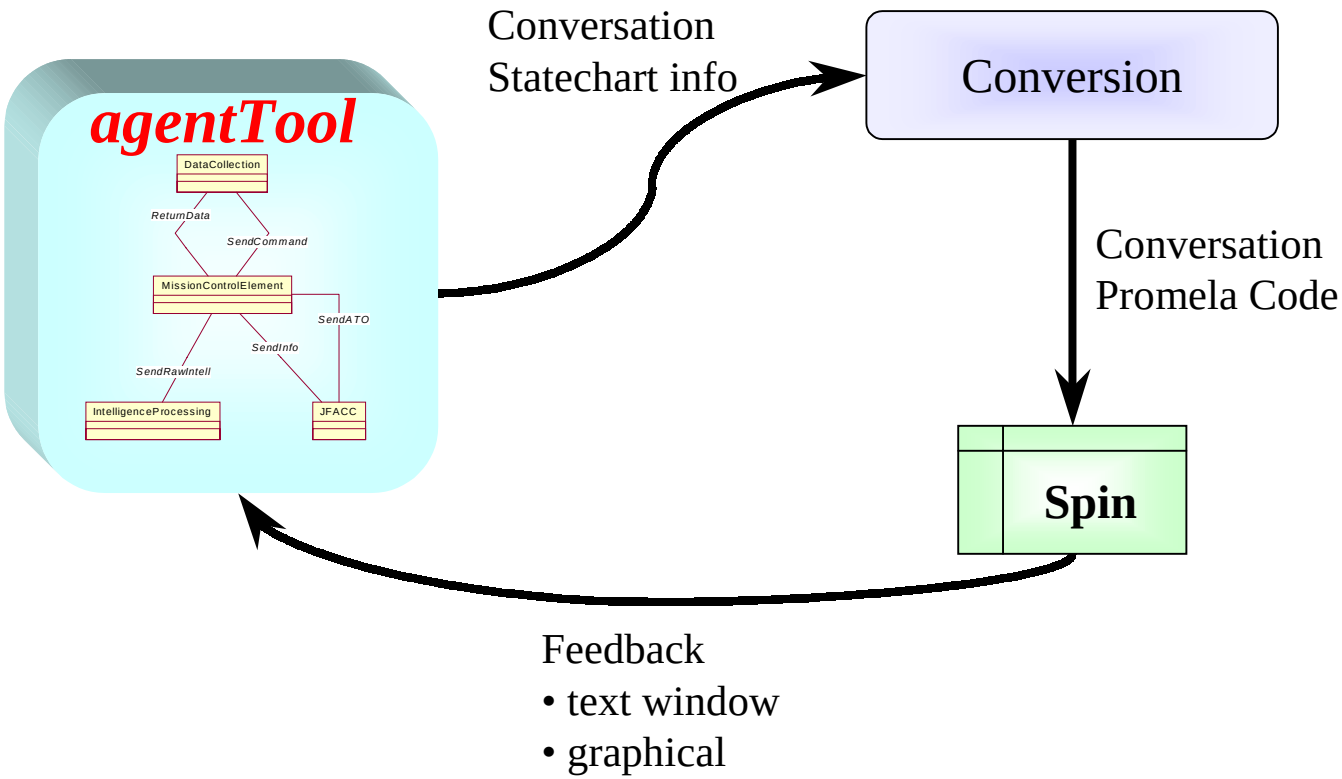
Code Generation

- Automatic from Agent and Conversation Diagrams
- Select platform-dependent components such as a messaging system
- Currently focused on agentMom



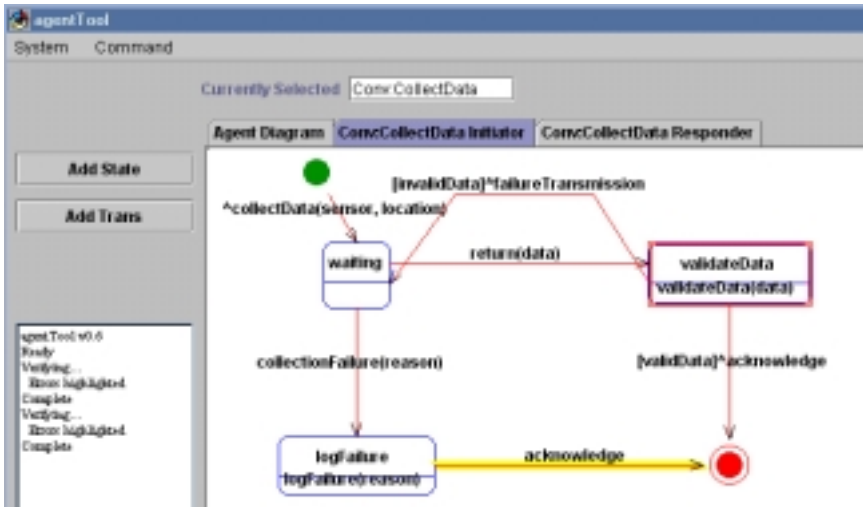


Verification Process



Feedback

```
proc 0 = :init:
proc 1 = SendInfoInitiator
proc 2 = SendInfoResponder
proc 3 = CollectDataInitiator
proc 4 = CollectDataResponder
q\p   0   1   2   3   4
  1   .   .   .   CollectData!collectData
  1   .   .   .   .   CollectData?collectData
  1   .   .   .   .   CollectData!collectionFailure
  1   .   .   .   CollectData?collectionFailure
  2   .   SendInfo!send
  2   .   .   SendInfo?send
  2   .   .   SendInfo!acknowledge
  2   .   SendInfo?acknowledge
spin: trail ends after 16 steps
-------------
final state:
-------------
#processes: 5
 16:           proc  4 (CollectDataResponder) line  92 "verify" (state 27)
proc  3 (CollectDataInitiator) line  65 "verify" (state 24)
proc  2 (SendInfoResponder) line  46 "verify" (state 24) <valid endstate>
proc  1 (SendInfoInitiator) line  25 "verify" (state 22) <valid endstate>
proc  0 (:init:) line 114 "verify" (state 6) <valid endstate>
5 processes created
```



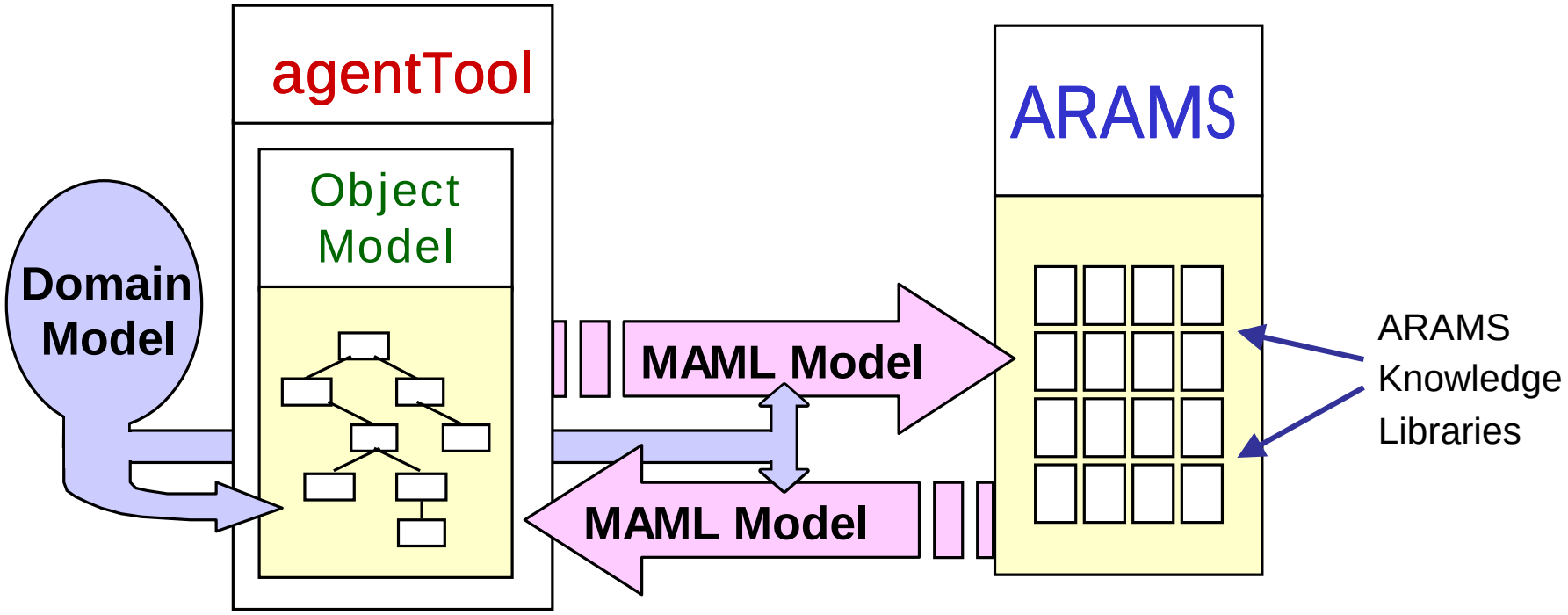

```
DEADLOCK CONDITION EXISTS IN THE FOLLOWING CONVERSATION:
Conversation Name = CollectData
Participant Name = Responder
Current State = wait
State Transition = acknowledge

DEADLOCK CONDITION EXISTS IN THE FOLLOWING CONVERSATION:
Conversation Name = CollectData
Participant Name = Initiator
Current State = logFailure
State Transition = acknowledge
```

Verification Capabilities

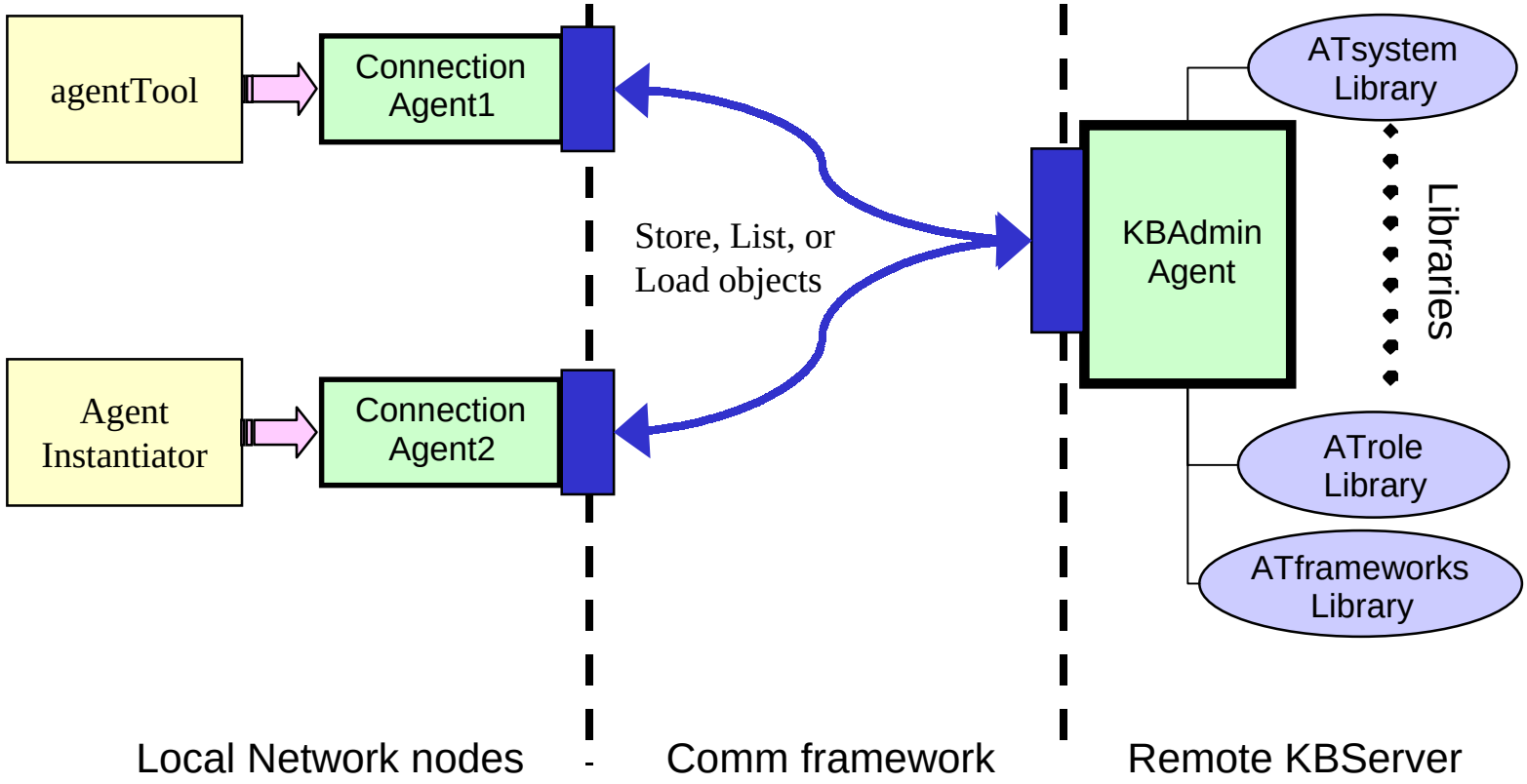
- Conversation deadlocks
- Non-progress loops
- Unused messages
- Mislabeled transitions
- Inability to create required sequences

Knowledge Base Overview

- Agent Random-Access Meta-Structure (ARAMS)
  - Java-based repository
- Multiagent Markup Language (MAML)
  - Key to interoperability – XML based



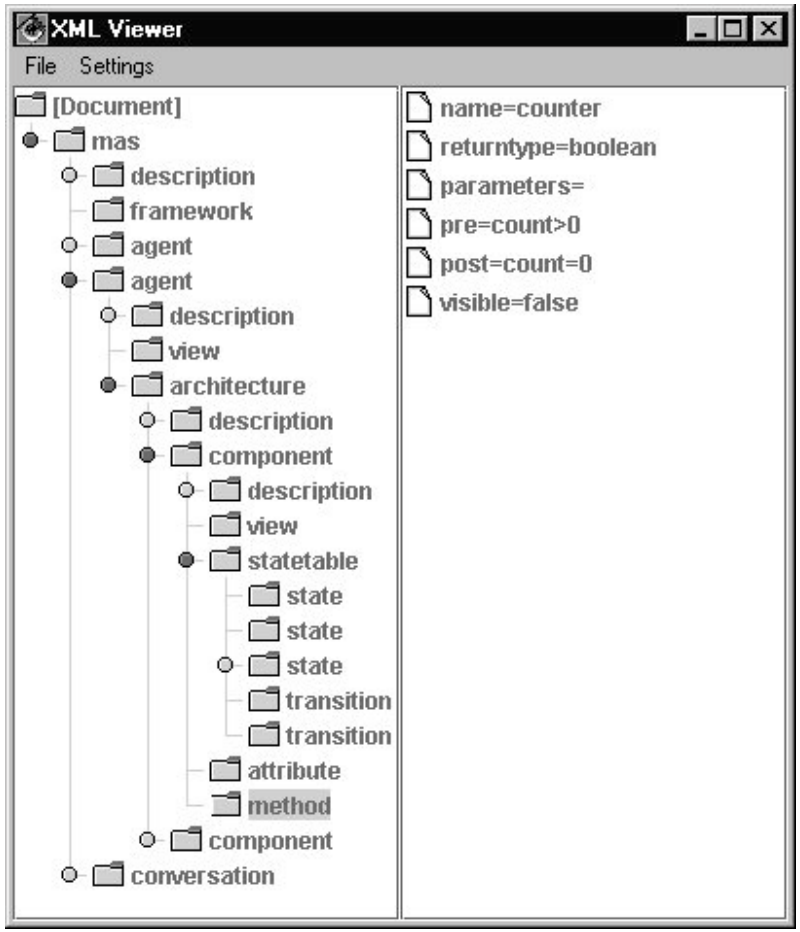
Knowledge Base Implementation



Multi-Agent Meta-Language (MAML)

- **Based on XML**
  - **Compatible with existing tools**
- **Example**

```
</agent>
  <agent version="1" name="Bidder">
     <description>
     none
     </description>
     <view x="421" y="102" w="50" h="50"/>
     <architecture version="1“ name="null">
        <description>
        none
        </description>
        </architecture>
  </agent>
```

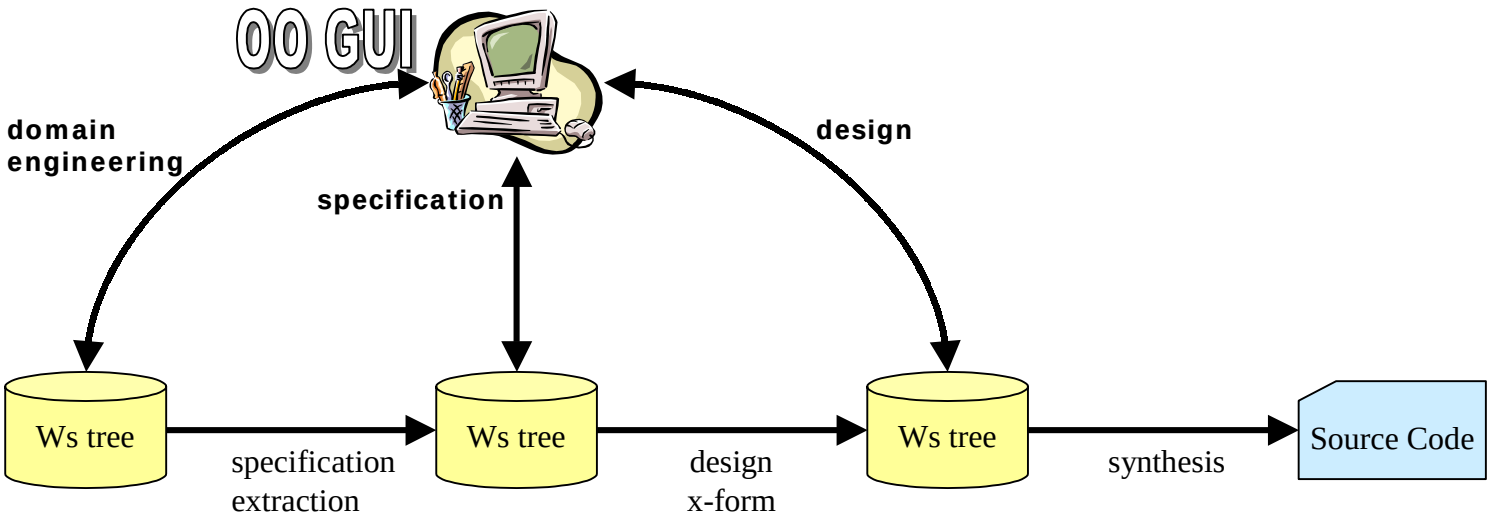


AFIT Wide-Spectrum Object Modeling Environment

(AWSOME)

AWSOME Environment

AFIT Wide-Spectrum Object Modeling Environment



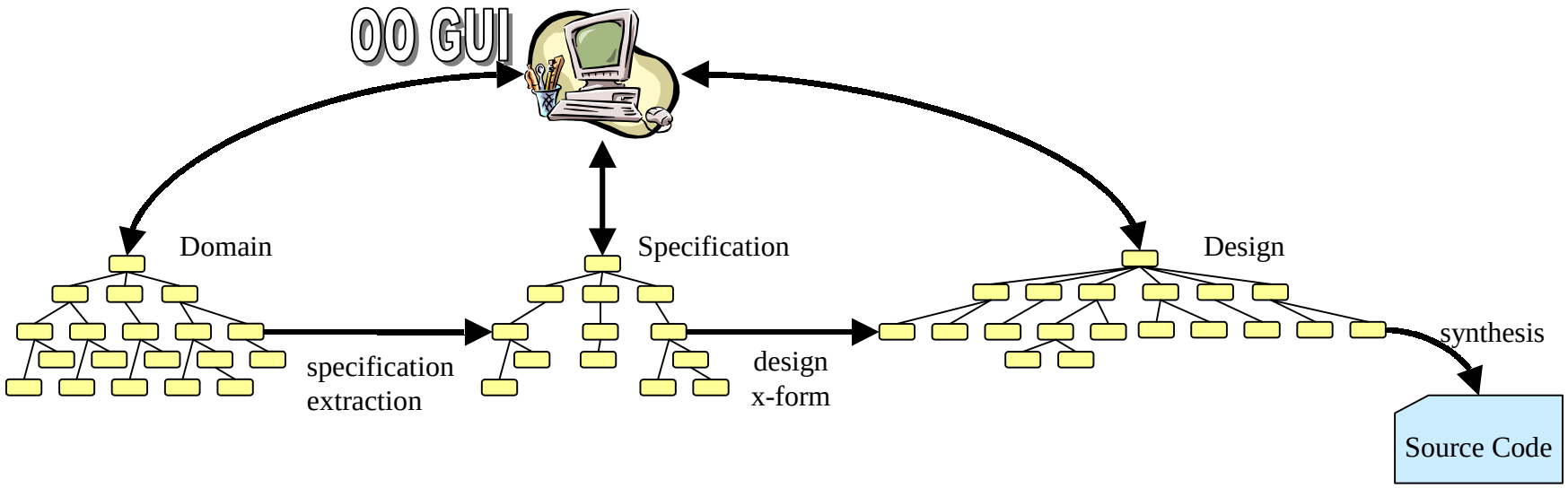
"Domain Tree"

"Specification Tree"

"Design Tree"

AWSOME Wide-Spectrum Modeling Language

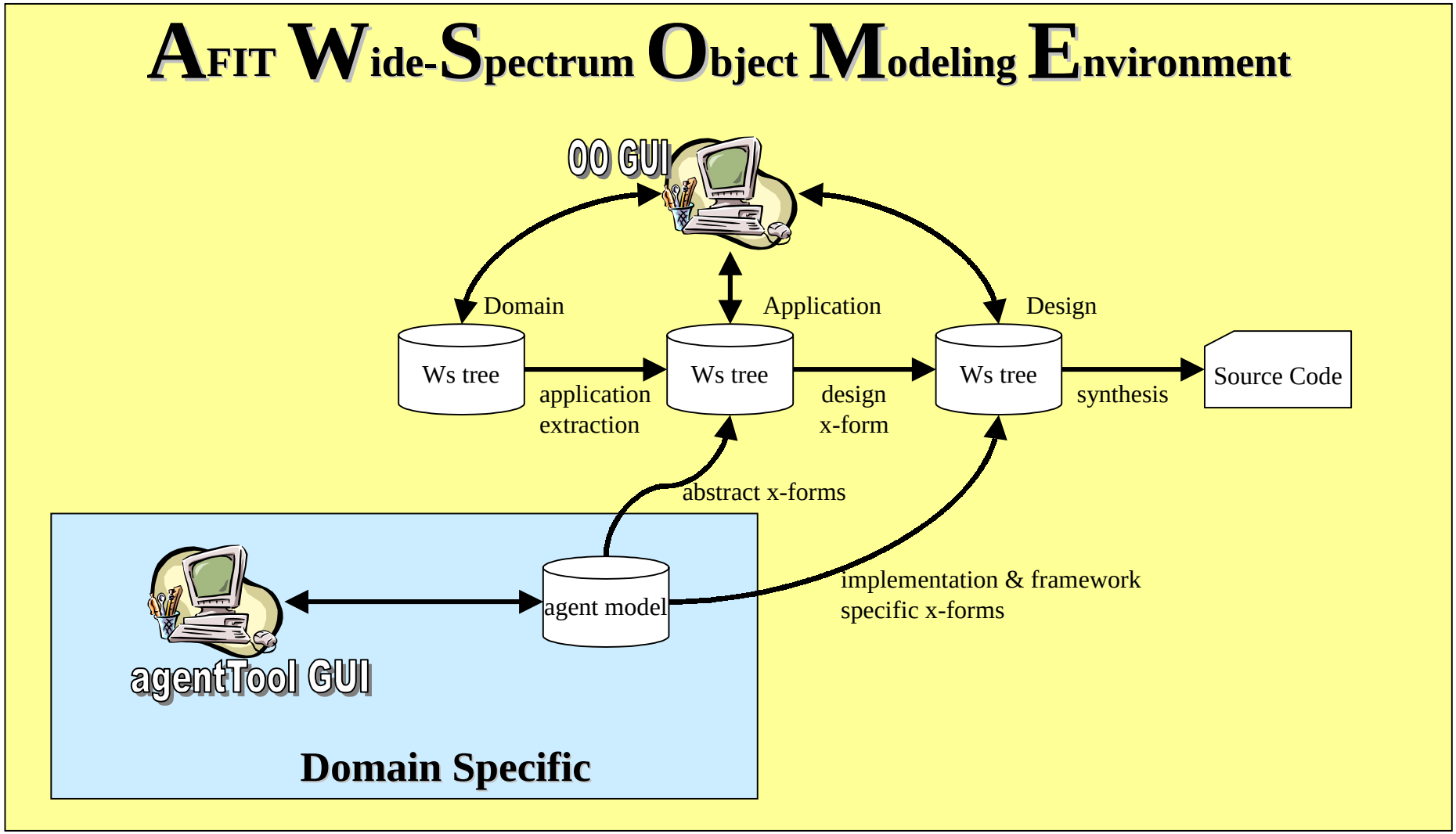
AFIT Wide-Spectrum Object Modeling Environment



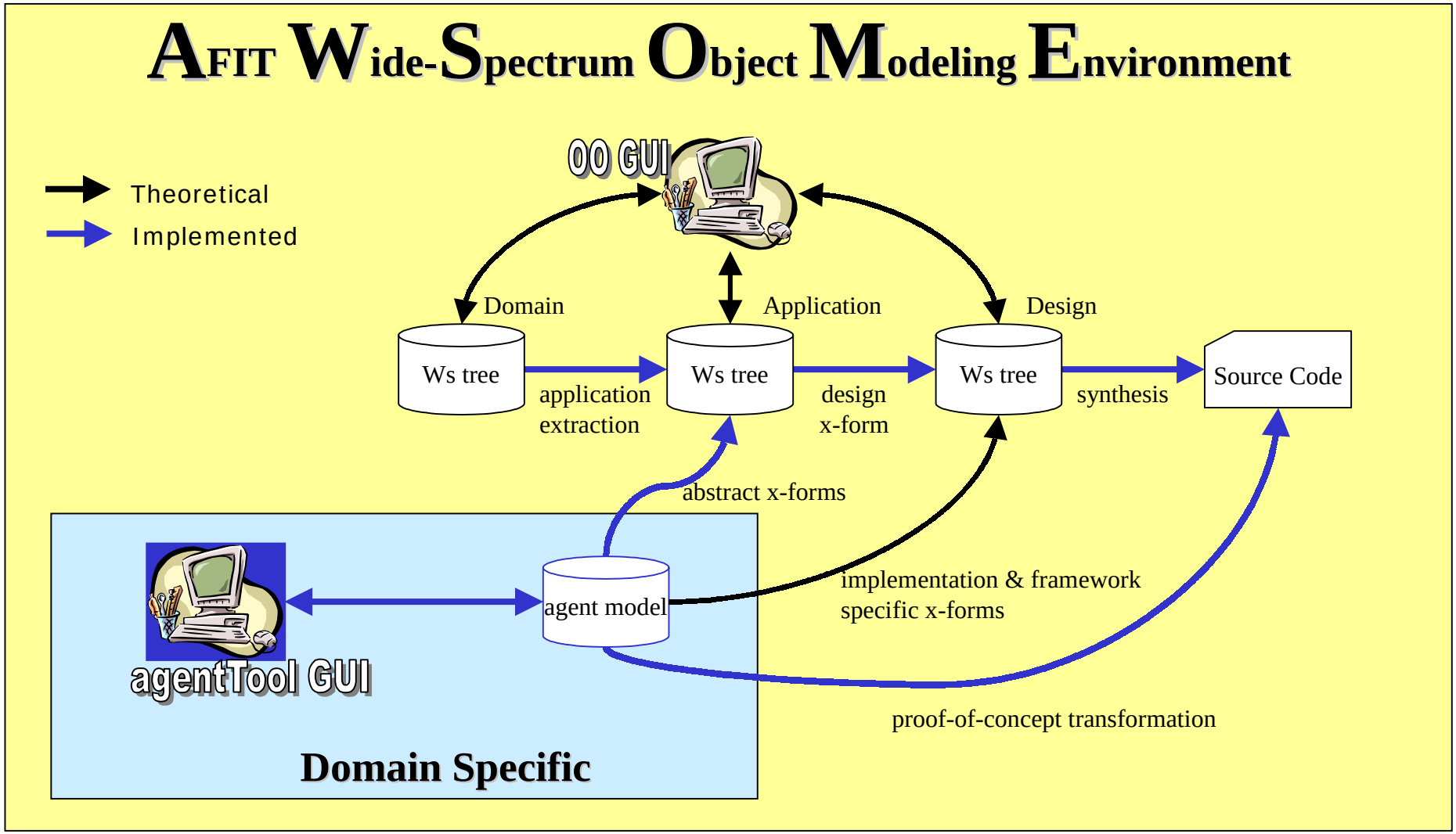
AWSOME Capabilities

- State model defined as formal spec
- Five formal transforms applied to spec
- Resulting design is object model
  - Methods to handle events
  - Method to mimic state transitions
- Java code generated from design model
  - Demonstrated with two agent systems
  - Intend to demonstrate with UConn's MADGS

Domain Specific Front Ends



Domain Specific Front Ends
(Implemented)



Future Direction

- Integration of domains
  - Reuse existing models
  - Communication protocols, security protocols, domain knowledge, etc.
- Detailed design
  - Mapping tasks to conversations and internal agent architectures
- Extend MaSE/agentTool
  - Mobility
  - Dynamic systems

Publications

- Journal – Foundational Work
  - Translating Graphically-Based Object-Oriented Specifications to Formal Specifications. submitted to ACM Transactions on Software Engineering and Methodology, Feb 2000.
  - A Theory-Based Representation for Object-Oriented Domain Models. accepted for publication in IEEE Transactions on Software Engineering, 1999.

Publications

- Conferences & Workshops
  - Developing Multiagent Systems with agentTool, submitted to 7th International Workshop on Agent Theories, Architectures, and Languages, Boston MA, July 2000.
  - An Overview of the Multiagent Systems Engineering Methodology. submitted to 1st International Workshop on Agent-Oriented Software Engineering, Limerick Ireland, June 2000.
  - Automatic Verification of Multiagent Conversations, to be presented at the 11th Annual Midwest Artificial Intelligence and Cognitive Science Conference, Fayetteville Arkansas, July 2000.
  - Design Issues for Mixed-Initiative Agent Systems, AAAI-99 Workshop on Mixed-Initiative Intelligence, Orlando FL, July 1999.
  - Multiagent Systems Engineering: A Methodology and Language for Designing Agent Systems, Agent-Oriented Information Systems '99, Seattle WA, May 99.